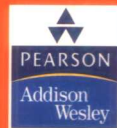




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—— 信息技术学科与电气工程学科系列

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Field and Wave Electromagnetics  
Second Edition

电磁场与电磁波(第2版)

David K. Cheng 著



清华大学出版社

**Second Edition**

# **Field and Wave Electromagnetics**

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**David K. Cheng**

Life Fellow, I.E.E.E.;  
Fellow, I.E.E.; C. Eng.

Tsinghua University Press

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# 出版说明

郑大钟

清华大学信息科学与技术学院

当前,在我国的高等学校中,教学内容和课程体系的改革已经成为教学改革中的一个非常突出的问题,而为数不少的课程教材中普遍存在的“课程体系老化,内容落伍时代,本研层次不清”的现象又是其中急需改变的一个重要方面。同时,随着科教兴国方针的贯彻落实,要求我们进一步转变观念扩大视野,使教学过程适应以信息技术为先导的技术革命和我国社会主义市场经济体制的需要,加快教学过程的国际化进程。在这方面,系统地研究和借鉴国外知名大学的相关教材,将会对推进我们的课程改革和推进我国大学教学的国际化进程,乃至对我们一些重点大学建设国际一流大学的努力,都将具有重要的借鉴推动作用。正是基于这种背景,我们决定在国内推出信息技术学科与电气工程学科国外知名大学原版系列教材。

本系列教材的组编将遵循如下的几点基本原则。(1)书目的范围限于信息技术学科和电气工程学科所属专业的技术基础课和主要的专业课。(2)教材的范围选自于具有较大影响且为国外知名大学所采用的教材。(3)教材属于在近5年内所出版的新书或新版书。(4)教材适合于作为我国大学相应课程的教材或主要教学参考书。(5)每本列选的教材都须经过国内相应领域的资深专家审读和推荐。(6)教材的形式直接以英文原版形式印刷出版。

本系列教材将按分期分批的方式组织出版。为了便于使用本系列教材的相关教师和学生从学科和教学的角度对其在体系和内容上的特点和特色有所了解,在每本教材中都附有我们所约请的相关领域资深教授撰写的影印版序言。此外,出于多样化的考虑,对于某些基本类型的课程,我们还同时列选了多于一本的不同体系、不同风格和不同层次的教材,以供不同要求和不同学时的同类课程的选用。

本系列教材的读者对象为信息技术学科和电气工程学科所属各专业的本科生,同时兼顾其他工程学科专业的本科生或研究生。本系列教材,既可采用作为相应课程的教材或教学参考书,也可提供作为工作于各个技术领域的工程师和技术人员的自学读物。

组编这套国外知名大学原版系列教材是一个尝试。不管是书目确定的合理性,教材选择的恰当性,还是评论看法的确切性,都有待于通过使用和实践来检验。感谢使用本系列教材的广大教师和学生的支持。期望广大读者提出意见和建议。

# Field and Wave Electromagnetics

## 影印版序

电磁场与电磁波是十分重要又十分难学的课程之一。电磁场是宇宙中普遍存在的一种物质形态,但是人们用肉眼只能看见以光波存在的电磁场,却看不到其他状态的电磁场,这就使得广大学习者感到电磁场理论的抽象。为了方便思维和构造电磁模型,科学家发明了电力线和磁力线,采用形象的几何图形结合数学公式的方式理解电磁场与电磁波。在大学本科和研究生教学中,电磁场与电磁波常常成为教与学都令人感到很困难的课程。其实,掌握这门学问的关键是建立和培养关于电磁场和电磁波的形象思维能力以及将物理结构和数学相结合的建模能力,这也成为有关电磁场与电磁波的课程中教师和学生应该共同完成的基本任务。

本书是关于电磁场与电磁波的一本很有特色的教材,取材新颖,笔法灵活,逻辑性强。教材从矢量分析和场论入手,以简捷清晰的方式建立了电磁模型。紧接着,全面地阐述了电磁场和电磁波的基础理论,包括静电场、静磁场、稳恒电流的场、边值问题的经典解法、时变电磁场与麦克斯韦方程组、平面电磁波及其传播、传输线、阻抗圆图、微带线、波导与谐振腔、天线与电磁辐射、电磁屏蔽等内容。本书除了内容全面之外,还具有很大的灵活性,这是因为全书的内容安排具有较完整的模块性,从而可以灵活地取舍和组合成适合不同行业 and 不同对象的电磁场与电磁波的教材。

本书配备了大量插图,版面整洁漂亮,非常有利于读者理解电磁场和电磁波过程,有利于读者潜移默化地建立起电磁场和电磁波的形象化的概念。书中采用的符号都是非常标准的,特别是采用了各种微分算符,使得公式的表达简洁、形象,便于理解。哲学家告诉我们,人类智力的成长要归功于语言能力和符号的艺术,面对电磁场理论的抽象性,在电磁场教科书中更应该突出相应的符号艺术。此外,将电磁场理论与电磁工程实际紧密结合也是本书的一大特点,书中配合电磁学理论的阐述列举了大量例题和习题,这些例题和习题都是取之于实际的电磁设备或电磁工程,具有相当强的实用性。通过这些例题和习题也介绍和剖析了许多电磁工程中的具体结构和原理,加之书中配备的各种参数的表格,使得该书对从事相关研究的读者来讲也是一本很有价值的参考书。

在全球一体化的今天,英语教材和英文授课对培养高水平人才有着不可估量的意

义,本书特别适宜选用作为理科大学本科高年级和工科院校硕士研究生基础课的英文授课教材或英文参考书。

Addison Wesley 图书公司出版了许多非常优秀的科技图书,该公司的出版物一直是广大科技工作者关注的热点。本书是 1983 年出版的,1989 年再版,目前影印的版本是 1992 年印刷的订正版本,这些都说明该书得到了极广泛的认可,已经成为世界性的经典教材。笔者读了本书竟爱不释手,因而推荐给同行专家和广大读者共享为快。现在,清华大学出版社出版本书影印版以飨读者,希望广大读者能从中受益。

吕英华 教授

北京邮电大学

2007 年 5 月

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## Preface

The many books on introductory electromagnetics can be roughly divided into two main groups. The first group takes the traditional development: starting with the experimental laws, generalizing them in steps, and finally synthesizing them in the form of Maxwell's equations. This is an inductive approach. The second group takes the axiomatic development: starting with Maxwell's equations, identifying each with the appropriate experimental law, and specializing the general equations to static and time-varying situations for analysis. This is a deductive approach. A few books begin with a treatment of the special theory of relativity and develop all of electromagnetic theory from Coulomb's law of force; but this approach requires the discussion and understanding of the special theory of relativity first and is perhaps best suited for a course at an advanced level.

Proponents of the traditional development argue that it is the way electromagnetic theory was unraveled historically (from special experimental laws to Maxwell's equations), and that it is easier for the students to follow than the other methods. I feel, however, that the way a body of knowledge was unraveled is not necessarily the best way to teach the subject to students. The topics tend to be fragmented and cannot take full advantage of the conciseness of vector calculus. Students are puzzled at, and often form a mental block to, the subsequent introduction of gradient, divergence, and curl operations. As a process for formulating an electromagnetic model, this approach lacks cohesiveness and elegance.

The axiomatic development usually begins with the set of four Maxwell's equations, either in differential or in integral form, as fundamental postulates. These are equations of considerable complexity and are difficult to master. They are likely to cause consternation and resistance in students who are hit with all of them at the beginning of a book. Alert students will wonder about the meaning of the field vectors and about the necessity and sufficiency of these general equations. At the initial stage students tend to be confused about the concepts of the electromagnetic model, and they are not yet comfortable with the associated mathematical manipulations. In any case, the general Maxwell's equations are soon simplified to apply to static fields,

which allow the consideration of electrostatic fields and magnetostatic fields separately. Why then should the entire set of four Maxwell's equations be introduced at the outset?

It may be argued that Coulomb's law, though based on experimental evidence, is in fact also a postulate. Consider the two stipulations of Coulomb's law: that the charged bodies are very small compared with their distance of separation, and that the force between the charged bodies is inversely proportional to the square of their distance. The question arises regarding the first stipulation: How small must the charged bodies be in order to be considered "very small" compared with their distance? In practice the charged bodies cannot be of vanishing sizes (ideal point charges), and there is difficulty in determining the "true" distance between two bodies of finite dimensions. For given body sizes the relative accuracy in distance measurements is better when the separation is larger. However, practical considerations (weakness of force, existence of extraneous charged bodies, etc.) restrict the usable distance of separation in the laboratory, and experimental inaccuracies cannot be entirely avoided. This leads to a more important question concerning the inverse-square relation of the second stipulation. Even if the charged bodies were of vanishing sizes, experimental measurements could not be of an infinite accuracy no matter how skillful and careful an experimenter was. How then was it possible for Coulomb to know that the force was *exactly* inversely proportional to the *square* (not the 2.000001th or the 1.999999th power) of the distance of separation? This question cannot be answered from an experimental viewpoint because it is not likely that during Coulomb's time experiments could have been accurate to the seventh place. We must therefore conclude that Coulomb's law is itself a postulate and that it is a law of nature discovered and assumed on the basis of his experiments of a limited accuracy (see Section 3-2).

This book builds the electromagnetic model using an *axiomatic approach in steps*: first for static electric fields (Chapter 3), then for static magnetic fields (Chapter 6), and finally for time-varying fields leading to Maxwell's equations (Chapter 7). The mathematical basis for each step is Helmholtz's theorem, which states that a vector field is determined to within an additive constant if both its divergence and its curl are specified everywhere. Thus, for the development of the electrostatic model in free space, it is only necessary to define a single vector (namely, the electric field intensity  $\mathbf{E}$ ) by specifying its divergence and its curl as postulates. All other relations in electrostatics for free space, including Coulomb's law and Gauss's law, can be derived from the two rather simple postulates. Relations in material media can be developed through the concept of equivalent charge distributions of polarized dielectrics.

Similarly, for the magnetostatic model in free space it is necessary to define only a single magnetic flux density vector  $\mathbf{B}$  by specifying its divergence and its curl as postulates; all other formulas can be derived from these two postulates. Relations in material media can be developed through the concept of equivalent current densities. Of course, the validity of the postulates lies in their ability to yield results that conform with experimental evidence.

For time-varying fields, the electric and magnetic field intensities are coupled. The curl  $\mathbf{E}$  postulate for the electrostatic model must be modified to conform with



Faraday's law. In addition, the curl  $\mathbf{B}$  postulate for the magnetostatic model must also be modified in order to be consistent with the equation of continuity. We have, then, the four Maxwell's equations that constitute the electromagnetic model. I believe that this gradual development of the electromagnetic model based on Helmholtz's theorem is novel, systematic, pedagogically sound, and more easily accepted by students.

In the presentation of the material, I strive for lucidity and unity, and for smooth and logical flow of ideas. Many worked-out examples are included to emphasize fundamental concepts and to illustrate methods for solving typical problems. Applications of derived relations to useful technologies (such as ink-jet printers, lightning arresters, electret microphones, cable design, multiconductor systems, electrostatic shielding, Doppler radar, radome design, Polaroid filters, satellite communication systems, optical fibers, and microstrip lines) are discussed. Review questions appear at the end of each chapter to test the students' retention and understanding of the essential material in the chapter. The problems in each chapter are designed to reinforce students' comprehension of the interrelationships between the different quantities in the formulas, and to extend their ability of applying the formulas to solve practical problems. In teaching, I have found the review questions a particularly useful device to stimulate students' interest and to keep them alert in class.

Besides the fundamentals of electromagnetic fields, this book also covers the theory and applications of transmission lines, waveguides and cavity resonators, and antennas and radiating systems. The fundamental concepts and the governing theory of electromagnetism do not change with the introduction of new electromagnetic devices. Ample reasons and incentives for learning the fundamental principles of electromagnetics are given in Section 1-1. I hope that the contents of this book, strengthened by the novel approach, will provide students with a secure and sufficient background for understanding and analyzing basic electromagnetic phenomena as well as prepare them for more advanced subjects in electromagnetic theory.

There is enough material in this book for a two-semester sequence of courses. Chapters 1 through 7 contain the material on fields, and Chapters 8 through 11 on waves and applications. In schools where there is only a one-semester course on electromagnetics, Chapters 1 through 7, plus the first four sections of Chapter 8 would provide a good foundation on fields and an introduction of waves in unbounded media. The remaining material could serve as a useful reference book on applications or as a textbook for a follow-up elective course. Schools on a quarter system could adjust the material to be covered in accordance with the total number of hours assigned to the subject of electromagnetics. Of course, individual instructors have the prerogative to emphasize and expand certain topics, and to deemphasize or delete certain others.

I have given considerable thought to the advisability of including computer programs for the solution of some problems, but have finally decided against it. Diverting students' attention and effort to numerical methods and computer software would distract them from concentrating on learning the fundamentals of electromagnetism. Where appropriate, the dependence of important results on the value of a parameter

is stressed by curves; field distributions and antenna patterns are illustrated by graphs; and typical mode patterns in waveguides are plotted. The computer programs for obtaining these curves, graphs, and mode patterns are not always simple. Students in science and engineering are required to acquire a facility for using computers; but the inclusion of some cookbook-style computer programs in a book on the fundamental principles of electromagnetic fields and waves would appear to contribute little to the understanding of the subject matter.

This book was first published in 1983. Favorable reactions and friendly encouragements from professors and students have provided me with the impetus to come out with a new edition. In this second edition I have added many new topics. These include Hall effect, d-c motors, transformers, eddy current, energy-transport velocity for wide-band signals in waveguides, radar equation and scattering cross section, transients in transmission lines, Bessel functions, circular waveguides and circular cavity resonators, waveguide discontinuities, wave propagation in ionosphere and near earth's surface, helical antennas, log-periodic dipole arrays, and antenna effective length and effective area. The total number of problems has been expanded by about 35 percent.

The Addison-Wesley Publishing Company has decided to make this second edition a two-color book. I think the readers will agree that the book is handsomely produced. I would like to take this opportunity to express my appreciation to all the people on the editorial, production, and marketing staff who provided help in bringing out this new edition. In particular, I wish to thank Thomas Robbins, Barbara Rifkind, Karen Myer, Joseph K. Vetere, and Katherine Harutunian.

*Chevy Chase, Maryland*

D. K. C.

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